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Sonar Baffles

Presentation at the Wayne Reader Memorial Session of the 129th Meeting of the Acoustical Society of America, 31 May 1995, Washington, DC

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PREFACE

This report was prepared under NUWC overhead funding and documents the presentation entitled "Sonar Baffles" which was presented at the Wayne Reader Memorial Session of the 129th Meeting of the Acoustical Society of America in Washington, DC.

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13. ABSTRACT (Maximum 200 words)

Acoustic decoupling baffles are often used to minimize noise contamination at hydrophone and transducer arrays. To maintain sensitivity near the nominally pressure release surface of the baffle, hydrophones can be placed at an odd multiple of a quarter wavelength from the baffle or near a heavy signal conditioning plate inserted between the hydrophones and the baffle. In either case, coherent interference between the incident wave and the wave reflected from the baffle limits the bandwidth of high sensitivity. Wayne Reader reasoned that by inserting a broadband absorber between the hydrophones and the decoupling baffle, a smoother hydrophone response could be attained of potentially less weight with relatively small loss in sensitivity. The talk describes the use of gradual transition absorbers developed by Wayne for sonar applications and his interactions with the author to combine these materials with broadband decouplers such as arrays of compliant tubes. His careful and thoughtful approach to the theoretical and experimental aspects of acoustic and material research was inspirational, and we miss his insight, advice, and encouragement.

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SONAR BAFFLES

Wayne Reader Memorial Session
129th Meeting of ASA
31 May 1995
Washington, DC

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The work described in this presentation concerns Dr. Wayne Reader's contribution to the development of sonar baffles.

I first met Wayne in 1972 at a Penn State course on Damping and Vibrations. The instructors included the august group of John Snowdon, Eugene Skudrzyk, Miguel Junger, Eric Unger, and Maurice Sevik. Not only were the presentations excellent, but the participants left with several texts which both Wayne and I used extensively.

When I had asked one of the lecturers about the similarities in a theoretical method that he described with that of a recently published dissertation, Wayne joined in on this discussion for he was also aware of the published work.

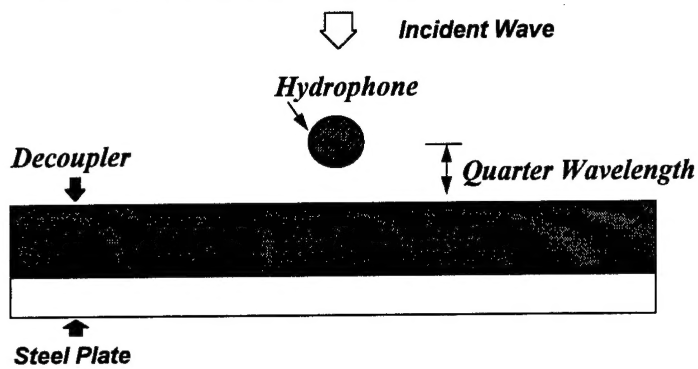
This initial conversation was the beginning of over twenty years of professional collaborations in the areas of target strength, materials research, transduction and environmental acoustics plus a lifetime personal friendship.

It was often at these meetings of the Acoustical Society of America that ideas were exchanged and projects initiated.

I would now like to describe some of the contributions which Wayne made in material research for sonar baffles with work that took place about 12 years ago.

Traditional Baffle Design With Decoupler

At a quarter wavelength spacing from a soft baffle, there is a pressure doubling for the direction of the incident wave normal to the baffle

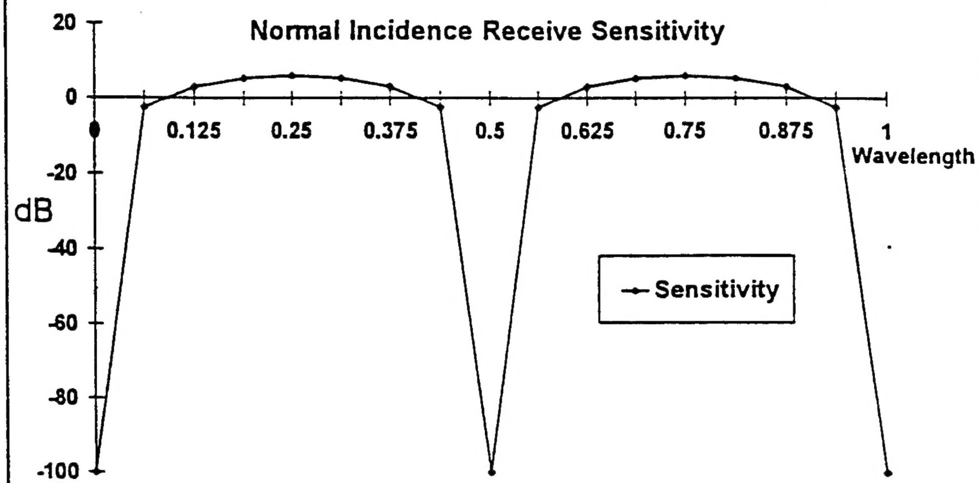


A decoupler, which is an approximation to a pressure release baffle, is typically used to provide a noise free environment for a hydrophone array.

Both flexural and acoustic waves emitted from the plate generate the background noise.

For the configuration shown, maximum hydrophone sensitivity for sensing an incoming pressure wave is attained when the center of the hydrophone is placed a quarter of a wavelength from the pressure release surface.

Quarter Wavelength Placement
of Hydrophone From Baffle



The response has regions of high and low sensitivity

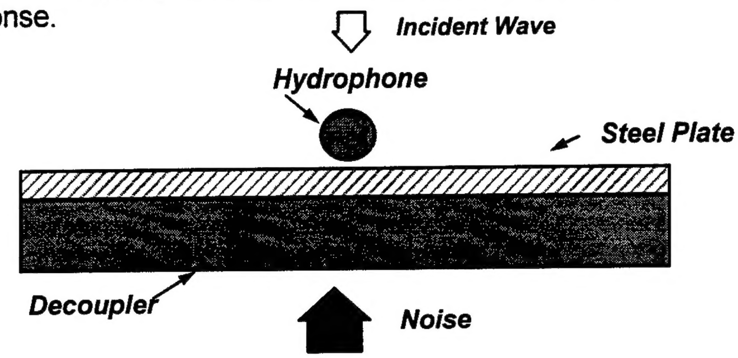
The graph of the hydrophone sensitivity for a plane wave normal to the baffle indicates that the receive response relative to the free field value of the hydrophone is at maximum when the center hydrophone is 1/4 and 3/4 of a wavelength distance from the decoupler.

However, at distances below 1/8 of a wavelength and near 1/2 of a wavelength from the baffle, the hydrophone sensitivity is low.

Thus, the region of high receive sensitivity has discontinuities as a function of frequency.

Traditional Baffle Design With Steel Plate and Decoupler

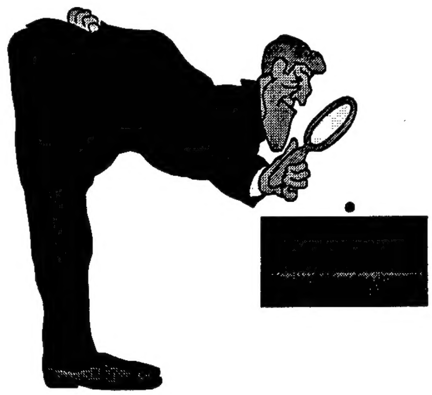
For maximum response, the hydrophone is placed next to the baffle. At low frequencies, the steel plate becomes transparent and a mass-spring resonance occurs that destroys the smooth response.



When a steel conditioning plate is inserted between the hydrophone and the baffle, low-frequency performance is improved but the plate eventually becomes acoustically transparent and a mass-spring resonance mitigates the smooth response.

At high frequencies the response is again periodic in nature with nulls occurring at 1/4, 3/4, etc. wavelength distances from the baffle.

Wayne Reader's Suggestions

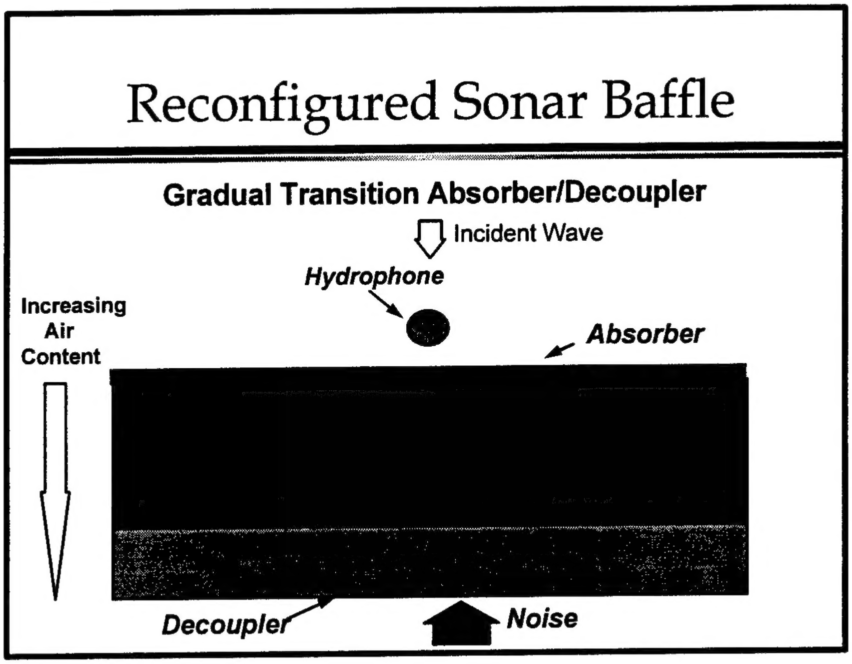


- Insert an absorber between the hydrophone and the baffle to smoothen the response.
- A broadband absorber would be optimal.
- Gradual transition absorbers are broadband.

The insertion of a broadband absorber between the hydrophone and the decoupler is a method of maintaining a smooth receive sensitivity.

The receive sensitivity is similar to that of the free field response.

If the thickness of the absorber is not a major consideration, a gradual transition layer absorber is a candidate material.



Near the hydrophone, the material needs to be a good impedance match to the rho-c of water to minimize reflections at the surface.

As the wave propagates through the thickness of the material, the air content of the material properties slowly increases such as to absorb the incident energy.

The decoupling characteristics must be maintained to minimize noise transmitting through the baffle to the hydrophone.

Low Frequency Performance

- To enhance the low frequency performance of a baffle of a given thickness, Dr. Reader suggested the use of resonant devices.
- Included were the following devices:
  - » cylindrical air cavities.
  - » compliant tubes.
  - » resonant piezoelectric cylinders.
- A joint project using compliant tubes was to demonstrate broadband echo reduction performance with a minimum goal of 6 dB together with improved insertion loss.

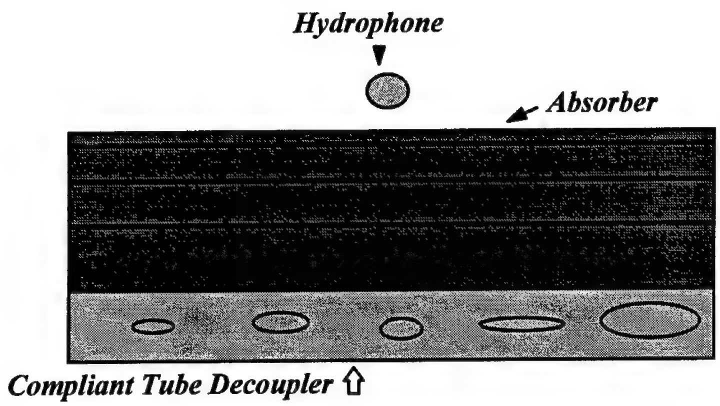
Often it is desirable to minimize the thickness of the sonar baffle. In this case, it may be possible for a given thickness to improve the performance at the lower end of the spectrum band of interest by inserting resonance devices.

Wayne investigated the use of large cylindrical air cavities and resonant piezoelectric cylinders. Wayne asked me to work with him to explore using compliant tube inclusions in the nominal decoupler portion of the baffle.

For a sonar baffle, the minimum goal was to achieve 6 dB of echo reduction and also improve the insertion loss or transmission loss.

Combination Baffle with Compliant Tubes

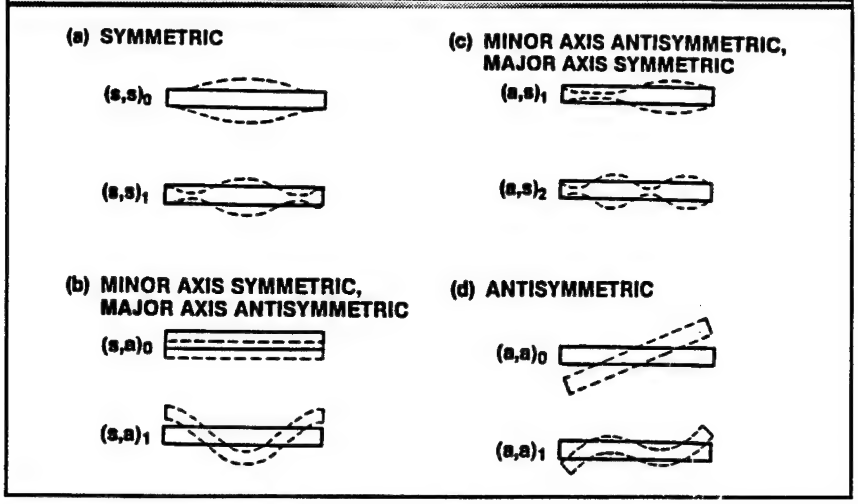
Compliant tubes have a net volume displacement (resonance) in the symmetric flexural modes



The conceptional combination baffles replaced the baseline baffle with configurations of periodic and random patterns of compliant tubes.

Although the tubes are often elliptical cylinders, for high aspect ratios, the bending can be approximated by connected plates.

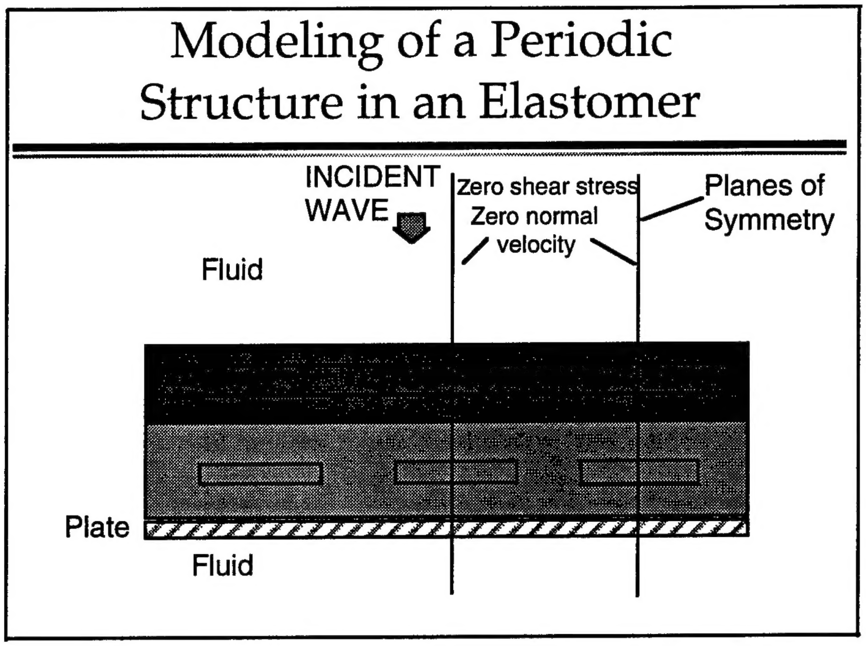
Compliant Tube
Bending Modes



The lower order bending modes for a traditional compliant tube are shown here. For the completely symmetric bending modes of the tube, a net volume change results in a resonance.

Since this bending mode occurs at a frequency lower than the extensional modes, the compliant tube is significantly smaller in size than for the first net volume mode for a right circular cylinder.

The non-compliant modes shown here tend to reduce the compliance of tube arrangements.



To attempt an optimization of the compliant structures, the model of periodic compliant tubes in a viscoelastic layer was extended to include Wayne's transition layer formulation for homogeneous mixtures with flexible microspheres.

By taking advantage of the periodicity of the configuration, a solution could be found for a periodic element with the boundary condition shown on the symmetry planes.

Mathematical Modeling of the Combination Baffles

- The fluid-like homogeneous mixture models of Chaban as employed by Dr. Reader were combined with the models of compliant tube gratings in a viscoelastic material.
- Only the periodic structures were considered.
- Compliant tubes treated by plate theory.
- Backing plate treated as an elastic plate.
- Series convergence was difficult for complex multilayered structures.

No model was developed for the random distribution of compliant tubes. Simple elastic plate functions had previously been found to describe the motion of the compliant inclusions.

For normal incident waves, no differences were found in treating the backing as elastic or as a fluid.

As more layers were added, or at the higher frequencies, the limited size of the solution matrix resulted in convergence difficulties in the series solutions. Thus only trends could be examined and not absolute solutions.

Conclusions

- Where thickness is not a consideration, gradual transition layer sonar baffles have been very successful.
- The use of resonance devices to enhance performance was demonstrated.
- Work continues on the material and modeling optimization.

Dr. James J. Dlubac and Richard J. Deigen of CDNSWC have continued the work with the gradual transition materials.

With current enhanced computational capabilities, any convergence problems that existed with the mathematical formulations should no longer be a factor.

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